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(54) Color mixing and control system for use in an electrostatographic printing machine

(57) A system and method for color mixing and control in a developing material-based electrostatographic printing system. A developing reservoir containing an operative solution of customer selectable colored developing material is continuously replenished with selectively variable amounts developing material of basic color components making up the operative solution by controlling the rate of replenishment of the various color components added to the supply reservoir. A filter series is used to measure the optical properties of the developing material in the supply reservoir so that the actual optical properties thereof can be brought into agreement with set of predetermined target optical properties. The present invention can be used to control and maintain the color of the developing material in the reservoir through continuous monitoring and correction in order to maintain a particular ratio of color components in the reservoir over extended periods associated with very long print runs. The present invention may also be utilized to mix a customer selectable color *in situ,* whereby approximate amounts of basic color component developing material are initially deposited and mixed in the developing material reservoir and the resultant developing material mixture is continually monitored and adjusted until the mixture reaches target optical properties.

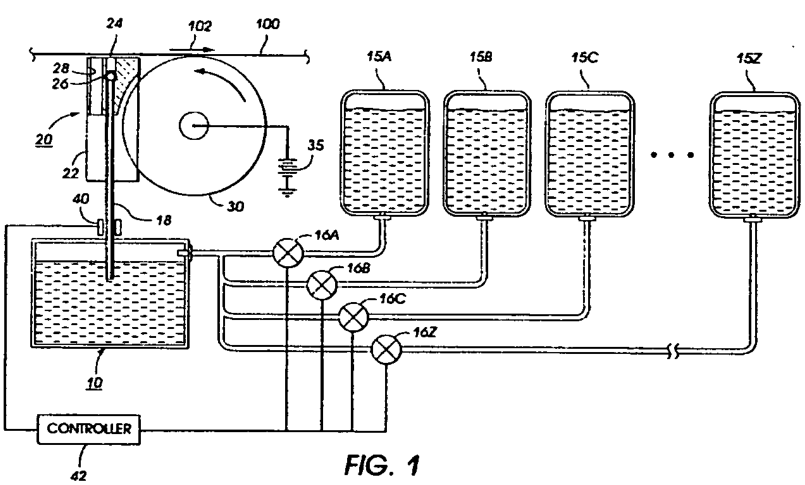

FIG. 1

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Printed by Jouve, 75001 PARIS (FR)

Description

This invention relates generally to a development system for creating color output images in an electrostatographic printing machine and, more particularly, concerns a system for providing customized color control in a liquid developing material-based electrostatographic printing system. The color mixing and control system operates by sensing the color of an operational mixture of developing material comprised of a blend of multiple basic color components and to further control the concentration of respective basic color components used to replenish the operational mixture.

It is well known that conventional electrostatographic reproduction processes can be adapted to produce multicolor images. For example, the charged photoconductive member may be sequentially exposed to a series of color separated images corresponding to the primary colors in an input image in order to form a plurality of color separated latent images. Each color separated image is developed with a complimentary developing material containing a primary color or a colorant which is the subtractive compliment of the color separated image, with each developed color separated image subsequently superimposed, in registration, on one another to produce a multicolor image output. Thus, a multicolor image is generated from patterns of different primary colors or their subtractive compliments which are blended by the eye to create a visual perception of a color image.

With the capabilities of electrostatographic technology moving into multicolor imaging, advances have also been directed to the creation of so-called "highlight color" images, wherein independent, differently colored, monochrome images are created on a single output copy sheet, preferably in a single processing cycle. Likewise, "spot color" and/ or "high-fidelity" color printing has been developed, wherein a printing system capable of producing process color output images is augmented with an additional developer housing containing an additional color beyond the primary or subtractive colors used to produce the process color output. This additional developer housing is used for developing an independent image with a specific color (spot color) or for extending the color gamut of the process color output (high fidelity color). As such, several concepts derived from conventional electrostatographic imaging techniques which were previously directed to monochrome and/or process color image formation have been modified to generate output images having selected areas that are different in color than the rest of the document. Applications of highlight color include, for example, emphasis on important information, accentuation of titles, and more generally, differentiation of specific areas of text or other image information.

One specific application of highlight color processing is customer selectable color printing, wherein a very specific highlight color is required. Customer selectable colors are typically utilized to provide instant identification and authenticity to a document. As such, the customer is usually highly concerned that the color meets particular color specifications. For example, the red color associated with Xerox' digital stylized "X" is a customer selectable color having a particular shade, hue and color value. Likewise, the particular shade of orange associated with Syracuse University is a good example of a customer selectable color. A more specialized example of a customer selectable color output can be found in the field of "custom color", which specifically refers to registered proprietary colors, as used, for example, in corporate logos, authorized letterhead and official seals. The yellow associated with Kodak brand products, and the brown associated with Hershey brand products are good examples of custom colors which are required to meet exacting color standards in a highlight color or spot color printing application.

The various colors typically utilized for standard highlighting processes generally do not precisely match customer selectable colors. Moreover, customer selectable colors typically cannot be accurately generated via halftone process color methods because the production of solid image areas of a particular color using halftone image processing techniques typically yields nonuniformity of the color in the image area. Further, lines and text produced by halftone process color are very sensitive to misregistration of the multiple color images such that blurring, color variances, and other image quality defects may result.

As a result of the deficiencies noted above, customer selectable color production in electrostatographic printing systems is typically carried out by providing a singular premixed developing material composition made up of a mixture of multiple color toner particles blended in preselected concentrations for producing the desired customer selectable color output. This method of mixing multiple color toners to produce a particular color developing material is analogous to processes used to produce customer selectable color paints and inks. In offset printing, for example, a customer selectable color output image is produced by printing a solid image pattern with a premixed customer selectable color printing ink as opposed to printing a plurality of halftone image patterns with various primary colors or compliments thereof. This concept has generally been extended to electrostatographic printing technology, as disclosed, for example, in commonly assigned U.S. Patent No. 5,557,393, wherein an electrostatic latent image is developed by a dry powder developing material comprising two or more compatible toner compositions to produce a customer selectable color output.

Customer selectable color printing materials including paints, printing inks and developing materials can be manufactured by determining precise amounts of constituent basic color components making up a given customer selectable color material, providing precisely measured amounts of each constituent basic color component, and thoroughly mixing these color components. This process is commonly facilitated by reference to a color guide or swatch book

containing hundreds or even thousands of swatches illustrating different colors, wherein each color swatch is associated with a specific formulation of colorants. Probably the most popular of these color guides is published by Pantone®, Inc. of Moonachie, New Jersey. The Pantone® Color Formula Guide expresses colors using a certified matching system and provides the precise formulation necessary to produce a specific customer selectable color by physically intermixing predetermined concentrations of up to four colors from a set of up to 18 principal or basic colors. There are many colors available using the Pantone® system or other color formula guides of this nature that cannot be produced via typical halftone process color methods or even by mixing selected amounts of cyan, magenta, yellow and/or black inks or developing materials.

The present invention contemplates a development system including a color mixing and control system, wherein the color value of the developing material in a supply reservoir can be controlled and the rate of replenishment of various color components added to the supply reservoir can be selectively varied. By adding and mixing precise amounts of specific developing materials from a set of basic color components, the actual color of the developing material in the reservoir is brought into agreement with a predetermined selected color. Moreover, by controlling the replenishment process accordingly, a wide range of customer selectable color developing materials can be produced and maintained over very long print runs.

In accordance with one aspect of the present invention, a system for providing a customer selectable color developing material in an electrostatographic printing machine is provided. The system comprises: a plurality of developing material supply receptacles, each containing a differently colored developing material concentrate corresponding to a basic color component of a color matching system; a developing material reservoir, having at least one of the plurality of developing material supply receptacles coupled thereto, for providing a supply of operative developing material having the specified color; and a system for systematically dispensing a selected amount of developing material concentrate from at least a selected one of the developing material supply receptacles to the developing material reservoir to provide a selected basic color component to the supply of operative developing material.

In accordance with another aspect of the present invention, there is provided an apparatus for developing an electrostatic latent image with a developing material having a specified color value. This developing apparatus comprises: a plurality of developing material supply dispensers, each containing a differently colored developing material concentrate corresponding to a basic color component of a color matching system; a developing material reservoir, for providing an operative supply of developing material having the specified color value.

In accordance with a further aspect of the present invention, an electrostatographic printing process is provided, wherein at least a portion of an electrostatic latent image is developed with a developing material having a specified color value. The process comprises the steps of: providing a plurality of differently colored developing concentrate materials corresponding to a plurality of basic color components of a color matching system; selectively delivering at least one of the plurality of differently colored developing concentrate materials to a developing material reservoir for producing an operative supply of developing material having the specified color value; and systematically dispensing a selected amount of developing material concentrate of a selected basic color component to the developing material reservoir for providing a selected basic color component to the operative supply of developing material.

Another aspect of the present invention is that the control system may also be utilized to mix a customer selectable color *in situ*, whereby approximate amounts of primary or basic color components are initially deposited and mixed in the developing material reservoir, with this developing material mixture being continually monitored and adjusted until the mixture meets some predetermined target optical properties.

Other aspects of the present invention will become apparent as the following description proceeds and upon reference to FIG. 1, which provides a schematic, elevational view of an exemplary liquid developing material applicator and an exemplary liquid developing material development system incorporating a liquid developing material color mixing and control system in accordance with the present invention. While the present invention will be described with respect to a liquid developing apparatus, it will be understood that the mixing and control system of the present invention is not limited to liquid developing materials and may be utilized in dry powder electrostatographic applications as well as liquid electrostatographic applications.

While the present invention may find particular application in tri-level highlight color imaging, it will become apparent from the following discussion that the color mixing and control system of the present invention may be equally well-suited for use in a wide variety of printing machines and is not necessarily limited in its application to any particular single-pass highlight tri-level electrostatographic process. In fact, it is intended that the color mixing and control system of the present invention may be extended to any electrostatographic printing process intended to produce a customer selectable color image area including multi-color printing machines which may be provided with an ancillary customer selectable color development housing, as well as printing machines which carry out ionographic printing processes and the like. More generally, while the color mixing and control system of the present invention will hereinafter be described in connection with a preferred embodiment thereof, it will be understood that the description of the invention is not intended to limit the scope of the present invention to this preferred embodiment. On the contrary, the present invention is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and

scope of the invention as defined by the appended claims.

Turning now to FIG. 1, an exemplary apparatus for developing an electrostatic latent image, wherein liquid developing materials are utilized is depicted in schematic form. Typically, a highlight color electrostatographic printing machine would include at least two developing apparatus operating with different color liquid developing materials for developing latent image areas into different colored visible images. By way of example, in a tri-level system of the type described hereinabove, a first developer apparatus might be utilized to develop the positively charged image area with black colored liquid developing material, while a second developer apparatus might be used to develop the negatively charged image area image with a customized color. In the case of liquid developing materials, each different color developing material comprises pigmented toner or marking particles, as well as charge control additives and charge directors, all disseminated through a liquid carrier, wherein the marking particles are charged to a polarity opposite in polarity to the charged latent image to be developed.

The developing apparatus of Fig. 1 operates primarily to transport liquid developer material into contact with a latent image on a photoreceptor surface, generally identified by reference numeral 100, wherein the marking particles are attracted, via electrophoresis, to the electrostatic latent image for creating a visible developed image thereof. With respect to the developing material transport and application process, the basic manner of operation of each developer apparatus is generally identical to one another and the developing apparatus shown in FIG. 1 represents only one of various known apparatus that can be utilized to apply liquid developing material to the photoconductive surface. It will be understood that the basic development system incorporating the mixing and control system of the present invention may be directed to either liquid or dry powder development and may take many forms, as for example, systems described in U.S. Patents 3,357,402; 3,618,552; 4,733,273; 4,883,018; 5,270,782 and 5,355,201. Such development systems may be utilized in a multicolor electrophotographic printing machine, a highlight color machine, or in a monochromatic printing machine.

Focusing on the development process before describing the color mixing and control system of the present invention, in the exemplary developing apparatus of FIG. 1, liquid developing material is transported from an supply reservoir 10 to the latent image on the photoreceptor 100 via a liquid developing material applicator 20. Supply reservoir 10 acts as a holding receptacle for providing an operative solution of liquid developing material comprised of liquid carrier, a charge director compound, and toner material, which, in the case of the customer selectable color application of the present invention, includes a blend of different colored marking particles. In accordance with the present invention, a plurality of replaceable supply dispensers 15A - 15Z, each containing a concentrated supply of marking particles and carrier liquid corresponding to a basic color component in a color matching system, are provided in association with the operational supply reservoir 10 and coupled thereto for replenishing the liquid developing material therein, as will be described.

The exemplary developing material applicator 20 includes a housing 22, having an elongated aperture 24 extending along a longitudinal axis thereof so as to be oriented substantially transverse to the surface of photoreceptor 100, along the direction of travel thereof, as indicated by arrow 102. The aperture 24 is coupled to an inlet port 26 which is further coupled to reservoir 10 via transport conduit 18. Transport conduit 18 operates in conjunction with aperture 24 to provide a path of travel for liquid developing material being transported from reservoir 10 and also defines a developing material application region in which the liquid developing material can freely flow in order to contact the surface of the photoreceptor belt 100 for developing the latent image thereon. Thus, liquid developing material is pumped or otherwise transported from the supply reservoir 10 to the applicator 20 through at least one inlet port 26, such that the liquid developing material flows out of the elongated aperture 24 and into contact with the surface of photoreceptor belt 100. An overflow drainage channel (not shown), partially surrounds the aperture 24, may also be provided for collecting excess developing material which may not be transferred over to the photoreceptor surface during development. Such an overflow channel would be connected to an outlet channel 28 for removal of excess or extraneous liquid developing material and, preferably, for directing this excess material back to reservoir 10 or to a waste sump whereat the liquid developing material can preferably be collected and the individual components thereof can be recycled for subsequent use.

Slightly downstream of and adjacent to the developing material applicator 20, in the direction of movement of the photoreceptor surface 100, is an electrically biased developer roller 30, the peripheral surface thereof being situated in close proximity to the surface of the photoreceptor 100. The developer roller 30 rotates in a direction opposite the movement of the photoconductor surface 100 so as to apply a substantial shear force to the thin layer of liquid developing material present in the area of the nip between the developer roller 30 and the photoreceptor 100, for minimizing the thickness of the liquid developing material on the surface thereof. This shear force removes a predetermined amount of excess liquid developing material from the surface of the photoreceptor and transports this excess developing material in the direction of the developing material applicator 20. The excess developing material eventually falls away from the rotating metering roll for collection in the reservoir 10 or a waste sump (not shown). A DC power supply 35 is also provided for maintaining an electrical bias on the metering roll 30 at a selected polarity and magnitude such that image areas of the electrostatic latent image on the photoconductive surface will attract marking particles from the

developing material for developing the electrostatic latent image. This electrophoretic development process minimizes the existence of marking particles in background regions and maximizes the deposit of marking particles in image areas on the photoreceptor.

In operation, liquid developing material is transported in the direction of the photoreceptor 100, filling the gap between the surface of the photoreceptor and the liquid developing material applicator 20. As the belt 100 moves in the direction of arrow 102, a portion of the liquid developing material in contact with the photoreceptor moves therewith toward the developing roll 30 where marking particles in the liquid developer material are attracted to the electrostatic latent image areas on the photoreceptor. The developing roller 30 also meters a predetermined amount of liquid developing material adhering to the photoconductive surface of belt 100 and acts as a seal for preventing extraneous liquid developing material from being carried away by the photoreceptor.

The application of developing material to the photoconductive surface clearly depletes the overall amount of the operative solution of developing material in supply reservoir 10. In the case of the liquid developing materials, marking particles are depleted in the image areas; carrier liquid is depleted in the image areas (trapped by marking particles) and in background areas, and may also be depleted by evaporation; and charge director is depleted in the image areas (trapped in the carrier liquid), in the image areas adsorbed onto marking particles, and in the background areas. In general practice, therefore, reservoir 10 is continuously replenished, as necessary, by the addition of developing material or selective components thereof, for example in the case of liquid developing materials, by the addition of liquid carrier, marking particles, and/or charge director into the supply reservoir 10. Since the total amount of any one component making up the developing material utilized to develop the image may vary as a function of the area of the developed image areas and the background portions of the latent image on the photoconductive surface, the specific amount of each component of the liquid developing material which must be added to the supply reservoir 10 varies with each development cycle. For example, a developed image having a large proportion of printed image area will cause a greater depletion of marking particles and/or charge director from a developing material reservoir as compared to a developed image with a small amount of printed image area.

Thus, it is known in the art that, while the rate of the replenishment of the liquid carrier component of the liquid developing material may be controlled by simply monitoring the level of liquid developer in the supply reservoir 10, the rate of replenishment of the marking particles, and/or the charge director components of the liquid developing material in reservoir 10 must be controlled in a more sophisticated manner to maintain the correct predetermined concentration for proper functionality of the marking particles and the charge director in the operative solution stored in the supply reservoir 10 (although the concentration may vary with time due to changes in operational parameters). Systems have been disclosed in the patent literature and otherwise for systematically replenishing individual components making up the liquid developing material (liquid carrier, marking particles and/or charge director) as they are depleted from the reservoir 10 during the development process. See, for example, commonly assigned U.S. Patent Application Serial No. 08/551,381 and the references cited therein.

The present invention, however, contemplates a developing material replenishing system capable of systematically replenishing individual color components making up a customer selectable color developing material composition. As such, the replenishment system of the present invention includes a plurality of differently colored concentrate supply dispensers 15A, 15B, 15C, ... 15Z, at least a pair of which are coupled to the operative supply reservoir via an associated valve member 16A, 16B 16C, ... 16Z, or other appropriate supply control device. Preferably, each supply dispenser contains a developing material concentrate of a known basic or primary color component used in a given color matching system. It will be understood that each of the plurality of supply dispensers 15A - 15Z may be coupled to the reservoir, or only selected supply dispensers may be coupled to the reservoir 10. For example, under certain circumstances, such as space constraints or cost restraints, it may be desirable to use only dispensers 15A, 15B and 15C, making up a simplified color matching system.

In one specific embodiment, the replenishment system includes sixteen supply dispensers, wherein each supply dispenser provides a different basic color developing material corresponding to the sixteen basic or constituent colors of the Pantone® Color Matching System such that color formulations conveniently provided thereby can be utilized to produce over a thousand desirable colors and shades in a customer selectable color printing environment. Using this system, as few as two different color developing materials, from supply containers 15A and 15B for example, can be combined in reservoir 10 to expand the color gamut of customer selectable colors far beyond the colors available via halftone imaging techniques or even the colors available from mixing just Yellow, Magenta, Cyan and Black colored developing materials.

An essential component of the developing material color mixing and control of the present invention is a mixing control system. That is, since different components of the blended or mixed developing material in reservoir 10 may develop at different rates, a customer selectable color mixing controller 42 is provided in order to determine appropriate amounts of each color developing material in supply containers 15A, 15B ... or 15Z which may need to be added to supply reservoir 10, and to controllably supply each of such appropriate amounts of developing material. Controller 42 may take the form of any known microprocessor based memory and processing device as are well known in the art.

The approach provided by the color mixing control system of the present invention includes a sensing device 40, for example an optical sensor for monitoring the color of the liquid developing material in the reservoir 10. It will be appreciated that although a spectrophotometric approach to color sensing may provide extremely rigorous color measurements, the high cost and computational demands may yield advantages to more basic technology. Thus, while sensor 40 can take various forms and could be of many types as are well known in the art, the preferred embodiment of the present invention includes a filter series for sensing the color of the developing material delivered out of the developing material reservoir 10 to the developing material applicator 20. The filter series contemplated by the present invention is represented diagramatically in FIG. 1 as sensing device 40, situated so as to sense the liquid developing material being transported from the liquid developing material reservoir 10 to the developing material applicator 20. It will be understood by those of skill in the art that various multi-wavelength filter devices may be utilized to detect the color of the developing material including devices which are submerged in the liquid developing material reservoir 10, or devices which monitor the light attenuation across the entire volume of the reservoir 10.

Sensor 40 is connected to controller 42 for controlling the flow of the variously colored replenishing liquid developing materials from dispensers 15A - 15Z, corresponding to the basic constituent colors of a color matching system, to be delivered into the liquid developing material supply reservoir 10 from each of the supply containers 15A - 15Z. In a preferred embodiment, as shown in FIG. 1, the controller 42 is coupled to control valves 16A - 16Z for selective actuation thereof to control the flow of liquid developing material from each supply container 15A - 15Z. It will be understood that these valves may be replaced by pump devices or any other suitable flow control mechanisms as known in the art, so as to be substituted thereby.

As previously noted, in accordance with the present invention, sensor 40 includes a filter series. As such, sensor 40 includes a suitable lamp, filters and a photodetector, wherein light is transmitted from the lamp through the filters and onto the developing material. The reflectance, transmission, or emission of the developing material as it is illuminated, in turn by the light passing through each filter. In a well recognized approach, a predetermined number of relatively narrow bandwidth filters having transmittance peaks distributed across the visible spectrum are utilized to determine the spectral distribution of a test sample, in this case, the developing material being sensed. By using a sufficient number of filters having filter transmittances which are confined to sufficiently narrow wavelengths, discernible spectral power distribution can be provided by the filter series so as to distinguish basic color components making up the developing material so as to define the color thereof.

The spectral distribution information can also be used to define the color of the developing materials in terms of a particular color coordinate system, such as, for example, the well recognized standardized color notation system for defining uniform color spaces developed by the Commission Internationale de l'Eclairage (CIE). The CIE color specification system employs so called "tristimulus values" to specify colors and to establish device independent color spaces. The CIE standards are widely accepted because measured colors can be readily expressed in the CIE recommended coordinate systems through the use of relatively straight-forward mathematical transformations.

Once the color for the monitored developing material is determined, the color of the measured sample, as may be defined by the spectral distribution or tristimulus values, among other units of measurement, is compared to the known values corresponding to the desired output color (as may be provided by the color matching system) to determine the precise color formulation necessary in the supply of operative developing material to yield a correct color match. This information is processed by controller 42 for selectively actuating valves 16A - 16Z to systematically dispense to the reservoir 10 selective amounts of developing material concentrate corresponding to selected basic color components from selected supply dispensers 15A - 15Z.

In sum, sensor 40 is provided in the form of a series of filter elements in combination with a light source and light detector for providing measurements that can be utilized to provide color mixing control. Measurements obtained from the filter series are compared to *a priori* knowledge of like optical properties of the basic color components making up the customer selectable color developing material to provide an estimate of the concentration levels of each color component in the reservoir as well as the correction necessary to obtain target concentration levels yielding the desired customer selectable color output. Thus, the filter series provides a measurement of selected optical properties of the blended developing material in the reservoir 10, wherein this optical property information is subsequently transmitted to the controller 42, which compares the measured optical property information to corresponding known optical property values of the desired output color, as may be stored in a look up table or the like of a memory device. This information is used to determine the appropriate amounts of each color component which should be added to the reservoir 10 via actuation of valves 16A - 16Z, respectively.

One method of carrying out the color mixing control process provided by the present invention will be described as follows: Initially, light passing through each filter is detected by a photodetector, producing a set of N filter signals, identified as f_n, corresponding to the number of filter elements, identified by the variable N. Assuming there are I developing material compositions corresponding to a number of basic color components utilized to produce the customer selectable color developing material, the composition of each color component making up the developing material passing through the filter, identified as w_i, can be calculated from the filter responses f_n, represented as follows:

$$\{w_i\}=F(\{f_n\})$$

One method of performing this calculation uses a previously determined matrix, A_{ni}:

$$w_i = \Sigma_n A_{ni} f_n$$

The A_{ni} are related in principle to the absorption spectra of the developing material components and to the transmission spectra of the filters. However, the A_{ni} can be most usefully obtained by fitting the filter signals from a known set of mixed developing materials. The accuracy of the w_i can be improved by using knowledge of which components are added to the mixed developing material.

In a first method by which this invention can be practiced, a set of filters is used which is equal to the total number of primaries or basic color components from which all customer selectable colors will be mixed. The transmission of light through each component and each filter is measured and the resulting matrix is inverted to obtain A_{ni}.

In a second method by which this invention can be practiced, a set of filters is used which need not be equal to the total number of primaries from which all customer selectable colors will be mixed. Filter responses of a large set of mixed toners are measured and A_{ni} is obtained by minimizing the RMS error between known and estimated concentrations, w_{ik}, for the ith component of the kth mixture.

In a third method by which this invention can be practiced, a set of filter responses and a set of known concentrations for a large set of mixed toners is used to train a neural net. The matrix multiplication defined above is replaced by a neural net calculation:

$$\{w_i\}=NN(\{f_n\})$$

where the braces denote that a set of filter functions is input to the neural net and a set of weights is output.

In a fourth method by which this invention can be practiced, a set of filters is used which need not be equal to the total number of primaries or basic color components from which all customer selectable colors will be mixed. In this method, filter responses of a large set of mixed developing materials are measured. Different sets of A_{ni} are obtained for different combinations of primary components. For example, a set of A_{ni} is obtained for each unique combination of primary developing materials, such as Yellow and Red; Yellow and Blue; Blue and Red; Yellow, Blue and Red; etc. Again, each set of A_{ni} is obtained by minimizing the RMS error between known and estimated concentrations, w_{ik}, for the ith component of the kth mixture in the set.

The performance of some of the above disclosed processes have been tested by modeling methods. For example, by selecting six colors, namely colors similar to: Pantone's Yellow; Warm Red; Rubine Red; Reflex Blue; Process Blue; and Green, as our primary set of basic colors. It has been estimated that this set will reproduce about 75% of the Pantone customer selectable colors. Transmission spectra for 70 mixtures of these primaries were calculated, wherein each mixed developing material has total solids of 1 wt% and 2-3 basic color components. Component concentrations differ from one mixture to the next by amounts as small as 0.01 wt%. Filter responses for idealized sets of Gaussian filters were also calculated, where each filter is specified by its center wavelength and its full width at half maximum transmission.

In one modeling example, using six 25nm wide filters, centered at 425, 475, 525, 575, 625, and 675 nm, respectively, it was found that the direct method of calculating component concentrations is only approximate and may yield non-zero concentration measurements for some basic color components which are not necessarily present in a given mixture, as well as some negative estimated concentrations. These erroneous calculations can be roughly corrected by substituting zero for all negative estimated concentrations and by using knowledge of the mixtures to force estimated concentrations of unused components to zero such that the RMS error in estimated concentrations can be substantially corrected. The RMS error in the individual component concentrations was about 0.36 wt%. Adjusting the filter positions and widths appropriately, an improved set of filters was determined as follows:

center (nm)	400	430	510	570	630	700
width (nm)	25	25	25	25	50	10

These new filters yielded an RMS error of 0.20 wt%. Of course, further optimization of the filter set may reduce the RMS error even further. However, these estimates may be sufficiently accurate for crude color control and may suffice for some applications.

In another example, the first set of six filters above was used to empirically adjust the A_{ni}, resulting in a reduction of the RMS error to approximately 0.067 wt%. In a similar manner, an empirical adjustment of the A_{ni} corresponding to the second filter set reduced the RMS error to 0.040 wt%, thus providing much more accurate color control than the first method.

In another experiment the test set of 70 mixtures was broken into subsets, each made of 2-3 primary developing materials. For each mixture subset, only the first filter set was utilized and a set of A_{ni} was empirically optimized, where i relates only to the primaries used in the mixture subset. For 13 mixtures of Yellow and Warm Red in the test set, empirical optimization of the 2x6 A_{ni} matrix reduced the RMS error to 0.001 wt%. For 8 mixtures of Yellow and Rubine Red in the test set, empirical optimization of the 2x6 A_{ni} matrix reduced the RMS error to 0.001 wt%. For 6 mixtures of Warm Red and Rubine Red in the test set, empirical optimization of the 2x6 A_{ni} matrix reduced the RMS error to less than 0.001 wt%. Since the test set contains only 3 mixtures of Yellow, Rubine Red, and Process Blue, the set was supplemented with three additional mixtures spanning a larger range of component compositions than the mixtures in the original test set. The resultant empirical optimization of the 3x6 A_{ni} matrix reduced the RMS error to 0.006 wt%. In addition, for 7 mixtures of Process Blue and Green in the test set, empirical optimization of the 2x6 A_{ni} matrix reduced the RMS error to 0.001 wt%. In all these cases, it was found that the accuracy of component concentration estimates is great enough to clearly distinguish all the colors in the test set for the color control system.

It will be understood that the foregoing methods represent a only a few of the numerous and various processes that could be implemented for controlling the mixture of color components using a series of filters in order to provide a specified color output.

In review, the present invention provides a system and method for color mixing control in an electrostatographic printing system. A developing reservoir containing an operative solution of customer selectable colored developing material is continuously replenished with the color thereof being controlled and maintained by selectively varying the rate of replenishment of various color components added to the supply reservoir. A series of filter elements is used to measure the optical properties of the developing material in the supply reservoir so that the corresponding optical properties thereof can be brought into agreement with corresponding target optical properties. The present invention can be used to control and maintain the color of the developing material in the reservoir through continuous monitoring and correction thereof in order to maintain a particular ratio of color components in the reservoir over extended periods associated with very long print runs. The present invention may also be utilized to mix a customer selectable color *in situ,* whereby approximate amounts of primary color components are initially deposited and mixed in the developing material reservoir, this developing material mixture being continually monitored and adjusted until the mixture reaches a some predetermined target optical properties.

Claims

1. A system for providing a customer selectable color developing material in an electrostatographic printing machine, comprising:

   a plurality of developing material supply receptacles (15A,15B,15C...15Z), each containing a differently colored developing material concentrate corresponding to a basic color component of a color matching system; and
   a developing material reservoir (10), having at least one of said plurality of developing material supply receptacles (15A,15B,15C...15Z) coupled thereto, for providing a supply of operative developing material having the specified color value.

2. The system of claim 1, further comprising a system for systematically dispensing a selected amount of developing material concentrate from at least a selected one of said developing material supply receptacles (15A,15B,15C... 15Z) to said developing material reservoir (10) to provide a selected basic color component to said supply of operative developing material.

3. The system of either of claims 1 or 2, further including a color sensing device (40) for monitoring the color of said supply of operative developing material.

4. The system of claim 3, wherein said sensing device (40) includes a filter series for measuring selected optical properties of said supply of operative developing material.

5. The system of any of claims 1 to 4, further including a control system (42) coupled to said sensing device (40) for selectively actuating said systematic dispensing system in response to the measured color of said supply of operative developing material, said control system (42) being operative to provide a customer selectable color de-

veloping material by blending a plurality of developing materials having different basic color components.

6. The system of any of claims 1 to 5, wherein the customer selectable color is selected from a color guide illustrating a plurality of different colors, wherein said color guide further provides a specific formulation of basic color components necessary to produce the supply of operative developing material, and further wherein said control system (42) is adapted to automatically blend predetermined amounts of basic color components in accordance with the specific formulation provided by said color guide.

7. The system of either of claims 5 or 6, wherein the control system (42) is adapted to compare optical properties of the supply of operative developing material from said sensing device (40) to respective target optical properties corresponding to said customer selectable color.

8. An apparatus for developing an electrostatic latent image with a developing material having a specified color, comprising:

   a plurality of developing material supply receptacles (15A,15B,15C...15Z), each containing a differently colored developing material concentrate corresponding to a basic color component of a color matching system; and
   a developing material reservoir (10), having at least two of said developing material supply receptacles (15A, 15B,15C...15Z) coupled thereto, for providing a supply of operative developing material having the specified color value.

9. The apparatus of claim 8, further comprising a system for systematically dispensing a selected amount of developing material concentrate from at least a selected one of said developing material supply receptacles (15A,15B, 15C...15Z) to said developing material reservoir to provide a selected basic color component to said supply of operative developing material.

10. An electrostatographic printing process wherein at least a portion of an electrostatic latent image is developed with a developing material having a specified color value, comprising the steps of:

   providing a plurality of differently colored developing concentrate materials, each corresponding to a basic color component of a color matching system;
   selectively delivering at least one of said plurality of differently colored developing concentrate materials to a developing material reservoir (10) for producing an operative supply of developing material having the specified color value; and
   systematically dispensing a selected amount of developing material concentrate of a selected basic color component to said developing material reservoir (10) for providing a selected basic color component to said operative supply of developing material.

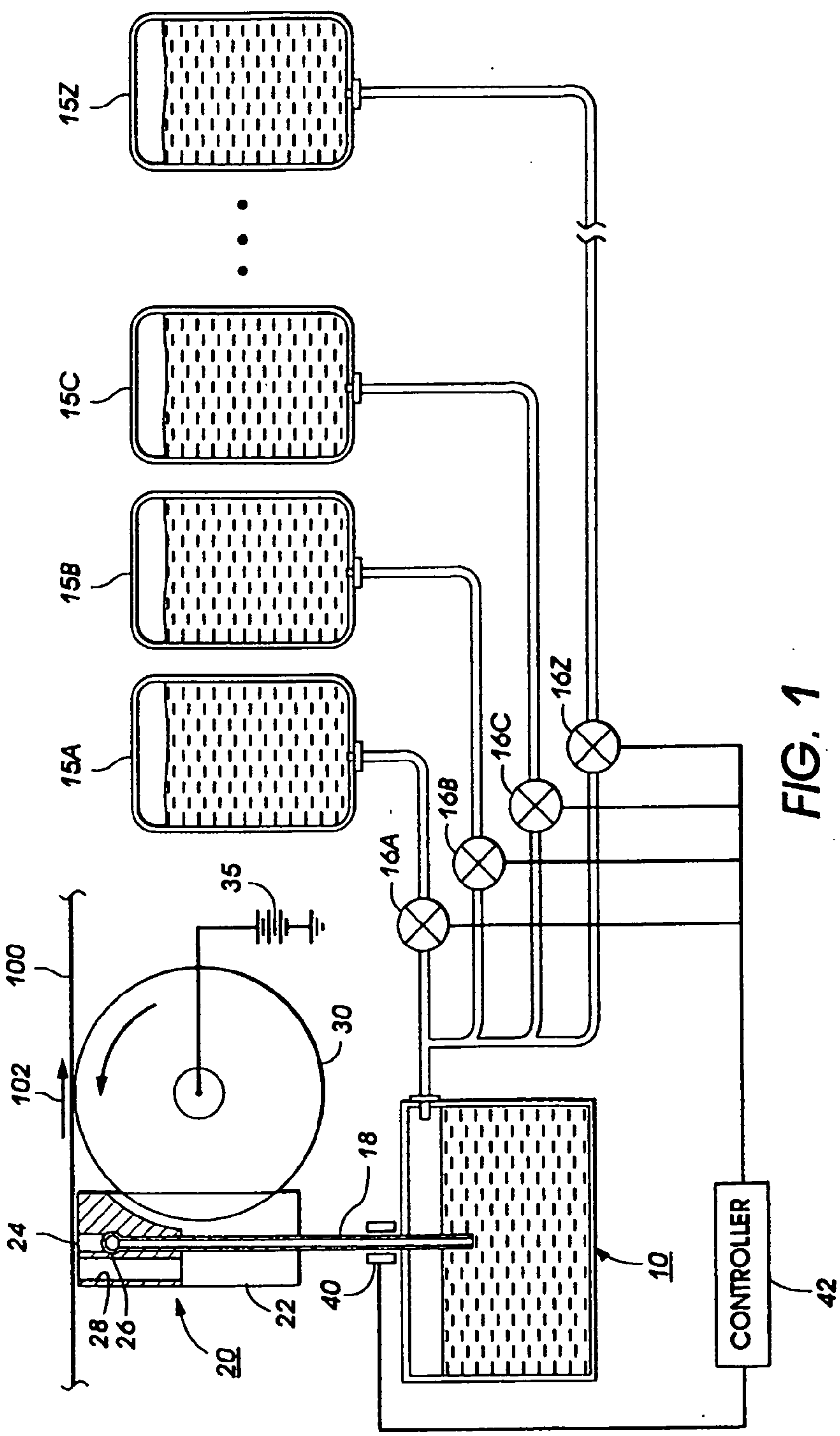
15A
15B
15C
15Z
16A
16B
16C
16Z
100
102
30
35
18
24
26
28
22
20
40
10
CONTROLLER
42

FIG. 1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 7326

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 4 111 151 A (RUCKDESCHEL FREDERICK R) * the whole document *	1-10	G03G15/10 G03G15/01 G03G15/08
X	US 4 113 371 A (FRASER LAWRENCE J ET AL) * the whole document *	1-10	
A	GOODMAN N B: "CUSTOM COLOR LIQUID INK DEVELOPMENT" XEROX DISCLOSURE JOURNAL, vol. 21, no. 2, 1 March 1996, page 155 XP000587140 * the whole document *	1,8,10	
D,A	US 5 557 393 A (GOODMAN NANCY B ET AL) * figures *	1,8,10	
P,A	PATENT ABSTRACTS OF JAPAN vol. 097, no. 001, 31 January 1997 & JP 08 248727 A (RICOH CO LTD), 27 September 1996, * abstract *	1,8,10	
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P,A	PATENT ABSTRACTS OF JAPAN vol. 097, no. 001, 31 January 1997 & JP 08 248719 A (RICOH CO LTD), 27 September 1996, * abstract *	1,8,10	G03G
A	DE 27 24 776 A (CANON KK) * the whole document *	1,8,10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	5 December 1997	Hoppe, H

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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